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ONE-CAVITY RESNATRON

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Fig. 1.

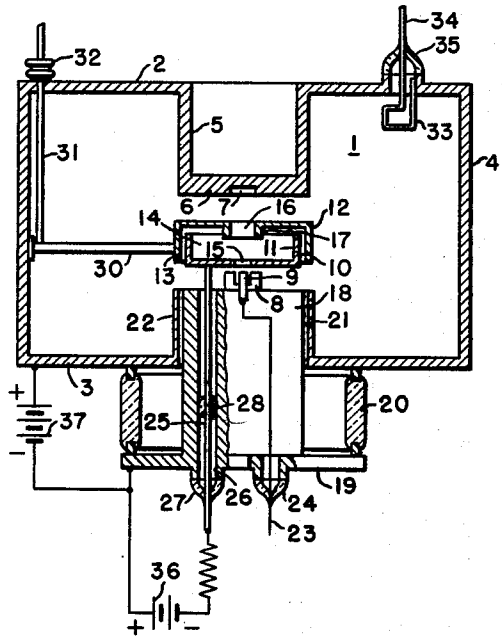
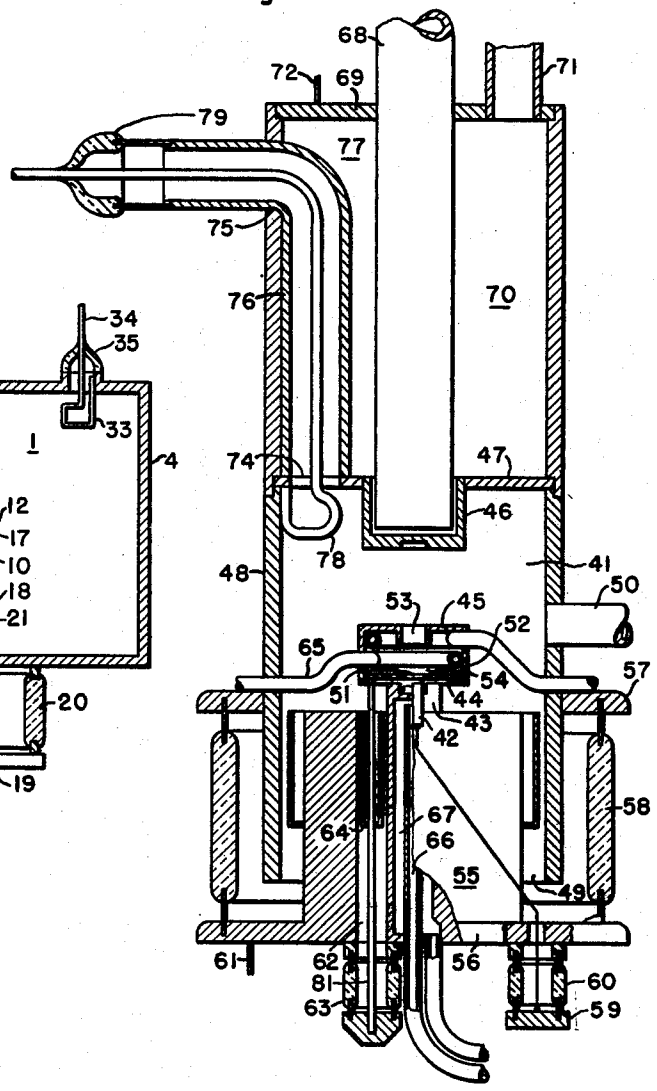


Fig. 2.



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ONE-CAVITY RESNATRON

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This invention relates generally to electronic vacuum tube structures and systems, and more particularly to broad band power tetrode oscillators, capable of operation in the ultra-high frequencies with high efficiency.

High power tetrode oscillators of the cavity resonator type are well known in the art relating to generation of ultra-high frequencies. One such tetrode arrangement, which has become known as the resnatron, and which has a theory of operation similar to that of the class C oscillator, has been found capable of delivering large amounts of power at high efficiencies over a wide band, in the ultra-high frequencies. The oscillating circuits of the device are cavities, which may be integral with the electronic elements of the tube.

In the usual resnatron structure two resonant cavities are employed. One, called the cathode cavity, is formed between the cathode and the control grid of the tube, and the other, known as the anode cavity, is formed between the anode and screen grid of the tube.

The electrodes of the tube normally form parts of the cylindrical walls of the cavities and are located substantially at positions of voltage maxima, with relation to standing waves set up in the cavities by oscillation of the tube, and the electron stream travels radially of the cavities.

Transit times are arranged to be such that electrons are supplied with energy in the cathode cavity and give up this energy in the anode cavity, and the electrons are bunched, not by velocity modulation, as in many ultra-high-frequency oscillators, but in response directly to grid - cathode potentials. The direct - current screen grid potential employed acts to accelerate electrons in the cathode cavity sufficiently to eliminate transit-time problems encountered in ultra-high-frequency triodes. The oscillators are tuned by controlling the size of the cavities, and oscillations are sustained by feeding back energy from the anode cavity to the cathode cavity. By omitting feed-back the tube may be caused to operate as an amplifier.

Since the conventional resnatron employs two cavities, which must be maintained critically tuned to each other despite the high Q values of the cavities, and more especially because of the high powers at which the resnatron operates, tuning problems are exceedingly difficult of solution, and extremely complex structural arrangements have, in the past, been resorted to for this purpose.

When resnatrons are utilized as oscillators,

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transit times at the operating voltages affect the phase of the feed-back from the anode cavity to the cathode cavity and these times become difficult to adjust. Usually an extremely large transit angle exists between cathode and control electrode, because electrons leave the cathode with small velocities. Further the electrons do not constitute anode current until they have passed the screen grid, so that transit time between control and screen grids must be considered. Measurements on conventional resnatrons indicate that transit angles of 30 to 120 degrees may be expected, depending on operating voltages and spacing of electrodes. Accordingly, high efficiency operation involves difficult adjustments.

Further difficulties exist by reason of the high interelectrode capacities existent in conventional resnatron tubes, which limit both the band width and the upper frequency normally attainable.

It is an object of the present invention to provide a novel resnatron oscillator tube and system.

It is a further object of the invention to provide a novel ultra-high-frequency tube, operating as a class C oscillator in accordance with principles employed in the conventional resnatron, but employing only a single resonant cavity.

It is a further object of the invention to provide a resnatron oscillator which is susceptible of simplified tuning, and which requires no complex structural arrangement for tuning.

It is another object of the invention to provide a resnatron oscillator in which correct phasing between the anode and cathode fields is readily established.

It is still another object of the invention to provide a resnatron oscillator capable of operation at higher frequencies than has heretofore been the case, by reason of the low effective interelectrode capacity established in the oscillator,

It is a further object of the invention to provide a novel ultra high frequency tube structure.

The above and still further objects, features and advantages of the invention will become apparent upon consideration of the following detailed description of a specific embodiment thereof, especially when taken in conjunction with the accompanying drawing, wherein

Figure 1 illustrates, largely in longitudinal section, an ultra high frequency tube in accordance with the invention, and

Figure 2 illustrates largely in longitudinal section, a modification of the tube of Figure 1.

Briefly described, resnatron tubes in accord-

ance with the present invention employ a single resonant cavity which functions both as an anode and cathode cavity. Thereby, the phase difference between the radio frequency field at the anode and cathode is established by the orientation of these elements, and is zero in the preferred embodiment of my invention. The transit distance may readily be selected to achieve maximum efficiency. The necessity for relative tuning of two cavities is avoided, which eliminates one extremely serious problem in conventional resnatrons. Further the grid-cathode and anode-screen capacities are effectively in series, which permits operation at higher frequencies than is possible with conventional resnatron structures, by enabling use of smaller interelectrode spacings.

Referring now more specifically to Figure 1 of the accompanying drawing, the reference numeral 1 identifies a single cylindrical cavity having a top wall 2, a lower wall 3 and a cylindrical side wall 4. A portion 5 of the upper wall 2, located co-axially of the cylindrical side wall 4, is nosed in to form an anode 6, the latter then being integral with the cavity structure. The anode 6 may preferably be circular, when viewed in plan, in order to afford symmetry with respect to the cylindrical side wall 4. Formed in the anode wall, and co-axially with the anode 6 is a depression or hollow 7, which serves to collect electrons emitted from a cathode 8. The cathode 8 is heated by means of a filament 9, associated with cathode 8 in conventional fashion.

A control electrode 10 is provided, in the form of a dish having annular walls or skirts 11, with its open end directed toward the anode 6. A screen grid 12 is further provided, in the form of an open dish having annular walls or skirts 13, with its open end in the direction of cathode 8, and with its annular walls or skirts 13 overlying the annular walls or skirts 11 of the control electrode 10, but spaced therefrom. Thereby is formed an intergrid space 14, shielded from the U. H. F. fields existing in the cavity 1, but subject to D.-C. fields radially of the cavity, and in the direction of travel of the electrons. To enable passage of the electrons emitted by the cathode 2 to the anode depression 7, apertures 15 and 16, co-axial with each other and with cathode 8 and anode depression 7, are provided in control grid 10 and screen grid 12, respectively. An inwardly extending annular rim 17, formed about the aperture 16, and extending inwardly of the intergrid cavity 14, is provided on the screen grid 12, for electro-optical reasons.

The cathode 8 may be supported by a generally cylindrical structure 18, which extends externally of the resonant cavity 1, and which may be provided with a flange 19 at its lower end, to serve as a support for a glass seal 20, extending from a suitable point of the outer surface of the lower wall 3 of the cavity 1 to the upper surface of the flange 19. The cathode support 18 may extend internally of the cavity 1 via a cylindrical open passageway 21 formed by nosing in a portion of the bottom wall 3 of the cavity 1 to form an inwardly extending cylindrical wall 22, open ended to permit access to the cavity.

The filament 9 may be supplied with heating current over a lead 23, which passes through the cathode support 19 via a glass seal 24 formed in the under surface thereof. The remaining filament terminal may be grounded to the cathode support 18, which is insulated from the

cavity structure 1 by the glass seal 20, and by virtue of the spacing between the wall portion 22 and the outer surface of the cylindrical cathode support 18. The control electrode 10 may be mounted on a metallic rod 25, passing through a passageway 26 in the cathode support 18, and providing a lead to the control electrode. The passageway 26 is preferably of cylindrical cross-section, and extends in a direction parallel to the axis of the cathode support 18. The control electrode lead and mounting 25 may be brought through the cathode support 18 by means of a glass seal 27, and at a suitable place in the passageway 26, and in contact with both the lead 25 or mounting and the inner wall of the passageway 26 may be placed a choke bucket 28. The position of the choke bucket 28 is so selected that the conductor 25 and the inner wall of the passageway 26 taken together form a choke for currents at the frequency of the cavity, thereby enabling the establishment of D.-C. insulation for the grid lead 25 without excessive loss of power. Similarly the space 21 between the cavity wall 22 and the outer wall of the cathode support 18 is designed to form a choke for currents at the frequency of operation of the cavity 1, to prevent transfer of energy externally of the cavity via the space 21.

The screen grid 12 may be mounted on support arms 30 and 31, the latter extending through the upper wall 2 of the cavity 1 via a bellows 32, which, in well known fashion, enables movement of the support arms 30 and 31 without affecting the vacuum within the cavity 1.

Output power may be derived from the cavity 1 by means of a loop 33 located within the cavity, and having one of its terminals connected to the inner cavity wall at any convenient point, and its remaining terminal 34 brought externally of the cavity through a glass seal 35.

Control electrode 10 may be biased for Class C operation by means of a potential source, illustrated merely for the sake of convenience as a battery 36, and connected with its negative terminal to the lead 25 and with its positive terminal to the cathode support 18. The anode 6 may be maintained at a suitable positive potential with respect to the cathode 8 by means of a voltage source, illustrated merely for purposes of simplification and convenience as a battery 37, connected between the cathode support 19 and any wall of the cavity. The screen grid 12 may be maintained at the same voltage as the anode 6 by means of a wiping contact 38, secured to the support arm 30, and maintained in contact with the inner cylindrical wall of the cavity 1 for all positions of the screen grid 12.

The cavity 1 may be tuned by motion of the screen grid 12 from and towards the anode 6, this motion being accomplished by moving the support arms 30 and 31, from externally of the cavity via bellows 32. This variation in tuning proceeds by virtue of the fact that variation of position of any metallic mass within a resonant cavity gives rises to variations of the tuning thereof, and further by reason of phase changes in anode current, which are controllable by the position of the screen grid of a resnatron oscillator. The phase difference between the radio frequency fields at the cathode and anode are established by the construction of the system, the latter two elements being immovable, and the phase difference may be so selected as to establish maximum efficiency. The total capacity in-

troduced into the resonator 1 by the presence of the cathode and grid structures is at a minimum by reason of the fact that the capacity between the control electrode 10 and the cathode 8 is in series with the capacity between anode 6 and screen grid 12, the total capacity being thus established at a value less than either of the capacities mentioned.

It will be noted that tuning of the cavity may be achieved by means of a single control, which simultaneously establishes all the resonant frequencies of the system, and that the tracking of the tuning of two cavities, which is necessary in resnatrons constructed in accordance with prior art principles, is totally avoided. Furthermore, tuning of the cavity is achieved without motion of any one surface which carries radio frequency currents with respect to another such surface while in direct contact with that other surface.

For optimum operation the distance between a point midway of the anode screen grid gap of the tube, and a point midway of the cathode control grid gap must be established such that the transit angle of electrons passing between the cathode and the anode is an odd multiple of π radians, at the frequency of operation of the system, since thereby electrons passing through the cathode grid gap at a positive peak of transit angle will arrive midway of the screen grid anode gap at a corresponding negative peak value later.

The structure of the control grid 10 and screen grid 12, and their overlapping skirts 11 and 13, is such as to provide a well shielded intergrid space 14, within which the electron beam passing to the cathode is accelerated substantially to anode voltage without phase change due to the radio frequency field. The structure of the cathode 8, the apertures 15 and 16 and the skirt 17 about the aperture 16 is designed to provide suitable electron optical parameters to establish a concentrated cylindrical beam of electrons within the screen anode gap.

Reference is now made to Figure 2 of the accompanying drawing, wherein is illustrated a modification of the system of Figure 1, which operates in accordance with the same general principles, but which presents certain refinements and variations of construction.

A single cylindrical cavity 41 is employed, having a cathode filament 42, a cathode body 43, a control electrode 44, an accelerator or screen grid 45, and an anode 46. The cavity 41 is provided with a top wall 47, and a cylindrical side wall 48, but is open at its bottom end, as at 49. The anode 46 may be constructed identically with the anode 6 of Figure 1. An evacuating lead 50 may be provided at a convenient point of the side wall 48, to enable maintenance of the necessary vacuum within the cavity 41.

The control electrode 44 may be provided in the form of a dish with a central opening 51 through which an electron beam may pass. Similarly the screen grid or accelerator 45 may take the form of an open dish having an annular, downwardly depending skirt 52, which extends below, the level of the control electrode 44 and outside the latter. The screen grid 45 may further comprise an axial aperture 53, aligned with the aperture 41, for passage for the electron beam generated during operation of the system. Thereby is formed an intergrid space 54, shielded from the ultra-high-frequency fields existing in the cavity 41, and within which the electron

beam is subject to direct current accelerating potentials.

The cathode filament 42 may be supported by the cathode body 43, in conventional fashion, the latter forming part of a generally cylindrical support structure 55, which extends externally of the cavity 41, via opening 49, and which may be provided with a flange 56 at its lower end, the latter being external to the cavity 41, and radially overlapping the cylindrical walls. A further flange 57 may be provided externally of the wall 48, and secured thereto, at a convenient location intermediate upper wall 47 and opening 49. The flange 57 may then be utilized as a support for the flange 56, by virtue of an insulating seal 58, fabricated of suitable glass or other suitable seal forming material, of generally cylindrical shape, and feathered into the flange 57 at its upper edge and into the flange 56 at its lower edge.

The filament 42 may be supplied with heating current over a lead 59, which passes through the support structure 55 via a glass seal 60 formed in the flange 56. The remaining filament terminal 61 may be grounded to the support structure 55, since the latter is insulated from the cavity structure 41 by the seal 58, and serves as a ground for filament 42.

The control electrode 44 may be fixed spaced with respect to the cathode body 43 and the filament 42, and may be mounted on a metallic rod 81, passing through a longitudinally extending passageway 62 in the support 55, and externally of the evacuated system via a glass seal 63. The metallic rod 81 then provides a lead to control electrode 44.

The passageway 62 is preferably of cylindrical cross-section, and of sufficiently great cross-section to contain a radio frequency choke 64, open adjacent the upper wall of support 55 and shorted to the metallic rod 81 at its lower end. Radio frequency choke 64 prevents leakage of radio frequency currents down the passageway 62, and provides an efficient mode of direct-current insulating the metallic rod 81, since the radio frequency choke 64 is not in contact with the support 55.

No supporting structure for screen grid or accelerator 45 is illustrated in Figure 2, it being clear that the expedient illustrated in Figure 1 is suitable for this purpose if desired. Alternatively, and as illustrated in Figure 2, the screen or accelerator 45 may be supported in fixed position by means of metallic tubing 65, coiled inside the grid structure and passing through the cylindrical wall 48 of the structure. The metallic tubing 65 may then be employed for conducting cooling fluid for cooling the screen or accelerator 45, and for conducting to the screen or accelerator 45 the requisite direct-current voltage. In the illustrated embodiment the tubing 65 passes directly through the metallic wall 48, and operates thereby to maintain screen or accelerator 45 at the same direct-current potential as anode 46. If desired the tubing 65 may be brought through wall 48 via insulated vacuum seals to enable screen or accelerator 45 to be maintained at a direct-current potential different than that of anode 46.

Cooling fluid for the cathode structure of the system is supplied via a duct 66 to the vicinity of the filament 42, and then returns via a duct 67, the ducts 66 and 67 being formed in the support structure 55.

A duct 68, for bringing cooling fluid to anode

46, may be provided, extending through the top wall 69 of a metallic cylindrical superstructure 70, supported on top wall 47. The duct 68 extends co-axially with anode 46, and into the nosed in anode structure. A further duct 71 is provided for egress of the cooling fluid. The superstructure 70 is at the same direct-current potential as the anode 46, and a direct-current anode lead 72 may accordingly be connected thereto.

Additionally an aperture 74 may be provided in wall 47, and a further aperture 75 in the cylindrical wall of superstructure 70, between which extends the outer conductor 76 of a co-axial transmission line 77. The inner end of the line 77 may terminate in a coupling loop 78, internally of the cavity 41, while the line 77, at its outer end may comprise a vacuum seal 79, externally of the superstructure 70.

The theory of operation of the systems illustrated in Figures 1 and 2 is the same, and hence the spacings of tube elements, and the dimensioning of ultra-high-frequency components may be derived from the same design considerations in each embodiment of the invention.

While I have described one specific embodiment of my invention, it will be clear that variations of structure may be resorted to without departing from the true scope of the invention as defined by the appended claims.

I claim as my invention:

1. A resnatron comprising a single cavity resonator having cylindrical symmetry, a cathode extending within one end wall of said cavity resonator, an anode comprised of the other end wall of said cavity resonator, a control electrode, said control electrode comprising a disc having an axial aperture and an annular skirt, means mounting said control electrode at a predetermined distance from said cathode, a screen electrode, means movably mounting said screen electrode between said anode and said control electrode, said screen electrode comprising a disc having an axial aperture and an annular skirt overlapping said first mentioned annular skirt and insulated therefrom, said cathode, anode and apertures being aligned with the axis of symmetry of said single cavity resonator, said cathode control electrode, screen electrode and anode being mutually insulated from one another for direct-current voltages.

2. In a tetrode electronic tube, a single cavity resonator, said single cavity resonator having cylindrical symmetry about a predetermined axis, an anode comprised of a portion of an end wall of said cavity, said anode having circular symmetry about said axis, a circular aperture in another end wall of said cavity, said circular aperture being symmetrical with respect to said axis, a cathode means mounting said cathode in said circular aperture and symmetrically with respect to said axis, a control electrode, means for mounting said control electrode intermediate said cathode and anode and insulatedly with respect to said cathode and anode, said control electrode having an aperture for passage of electrons, said control electrode possessing circular symmetry with respect to said axis with the aperture therein aligned with said axis, a screen electrode having an aperture for passage of electrons, means for mounting said screen electrode between said anode and said control electrode, said screen electrode possessing circular symmetry with respect to said axis with the aperture therein aligned with said axis, means connected to said screen electrode for varying the spacing between said screen electrode and said anode.

3. The combination in accordance with claim 2 wherein said screen and control electrodes comprise mutually overlapping skirts for insulating the space between said screen and control electrodes with respect to high-frequency electric fields in said single cavity resonator.

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